FORESTAR:
A decision-support system for multi-objective forest management in Northeast China

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Abstract: Past monoculture forestry in China has contributed to countrywide ecological disasters and economic difficulties in forestry regions. China's new forestry programs, Natural Forest Conservation Program and Returning Farmlands to Forests Program, provide opportunities for ecosystem management of mountain forests in China. A decision support system, FORESTAR, has been developed for better managing and protecting natural forests in Changbai Mountain area. It uses GIS-based forest inventory data at a scale of forestry bureau. The first version contains two sub-modules: forest operation and forest restoration. Under each sub-module, users can compare several decision options and make optimal choices. It can help field foresters, forest managers, and policy makers make multi-objective and consistent decisions in planning forest management at hierarchical administrative scales.

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Introduction

Decision-making in forestry is complicated but important because, in part, forests have a long lifespan and any wrong decisions in forest management can lead to ecological and economic disasters that will need a long time to recover if recoverable. Tremendous efforts have been made worldwide in developing decision support systems (DSS) in forestry. The fundamental intent of decision support systems for forest managers is to provide efficient, explicit, and explainable means of choosing among alternative courses of action based on available information and outcome preferences (Rauscher 1999). Different DSS share common generic theories but focus on different forestry tasks. For example, BOREAL (Puttock *et al.* 1998) aids forest managers in developing site-specific management schedules consistent with planning objectives and environmental standards; LEEMATH (Li *et al.* 2002) is to evaluates alternative management strategies from both economic and ecological perspectives; SBW DSS (Maclean *et al.* 2001) incorporates the effects of insect damage into forest management planning; and REGEN (Haddon *et al.* 1996) reports on forest regeneration activities and conditions on harvested lands. Rauscher (1999) classified 33 DSS developed in the United States into regional, forest, and project level DSS.

China has experienced excessive exploitations of natural forests and countrywide development of monoculture forest plantations (Zhao and Shao 2002). Although forest plantations have helped triple forest cover during the past 50 years, they could not help prevent ecological disasters caused by the loss of natural forests in mountainous areas, the origins of major river systems in China. In 1998, the most destructive flooding in China's recent history took place in the major river systems, causing at least US$20 billion in damage. The Three Gorge Dam under construction on Yangtze River will be the largest dam in the world when it is completed in 2009. The life of the dam will be threatened by increasingly more sediment accumulation in the river. The conservation and management of mountain forests are becoming a sociopolitical issue and challenging forest managers and scientists (Zhang *et al.* 2000). China is implementing two forestry programs, which provide excellent opportunities for a transition from timber-oriented forestry to ecosystem management of forest resources (Zhao and Shao 2002). Scientists in China understand what should be done in theory; politicians seem supportive to scientists' opinions; the major difficulties are the implementations of sound forestry programs. One of the reasons is that local foresters are not prepared for practicing ecosystem management. Decision support systems need to be developed to help with the transition from timber-oriented forestry to ecosystem management of forest resources.

New forestry programs and their needs

To control severe soil erosion in the upper reaches of major basins, to restore sustainable forestry, to conserve

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biodiversity, and to protect eco-environments, the central government formulated two forestry programs: Natural Forest Conservation Program (NFCP) (Zhang *et al.* 2000, Zhao and Shao 2002) and Returning Farmlands to Forests Program (RFFP) (Wu 2001, People's Daily 2002).

The NFCP focuses on the protection of natural forests in 18 provinces and autonomous regions, including the upstream regions of the Yellow River and Yangtze River and the state-owned forest industries in northern and northeastern China and Hainan Province. The program was designed to run from 1998 to 2010. Annual logging from state-owned forests is reduced by nearly 50% due to the implementation of NFCP. The central government provides financial support to help hundreds of thousands of laid-off forestry workers pursue new careers. The total costs of NFCP exceed US$13 billion.

The RFFP is aimed at the conversion of farmlands on steep slopes, greater than 25 degrees, to forests, shrubs, or grasslands in the middle and upper reaches of the Yellow River and Yangtze River basins. The central government provides farmers who lost the land they farmed with more financial support and free food than the farmers could make and produce with their farming. RFFP was initiated in 2000 at 174 trial counties and is now being formally implemented in 1 580 counties. The RFFP runs until 2010 with the total investment exceeding US$12 billion.

Both the NFCP and RFFP provide excellent opportunities to strengthen the sustainability of mountain forests and adopt forest ecosystem management in China. However, the sound implementation of the new programs has to be based on the following premises:

Firstly, accurate and consistent information on forest resources needs to be collected, digitized, and standardized. China has a 10-year-interval forest inventory program but the interpretation of the inventory data varies among different hierarchical government units. There are conflicts between local-level resources and higher-level official numbers.

Secondly, the scientific understanding and criteria of ecosystem management need to be translated into management action. In NFCP areas, long-term complete protection of natural forests is neither practical nor affordable; in RFFP areas, careless development of forest plantations will likely repeat the past monoculture forestry mistakes. In both cases, practicing forest ecosystem management is a necessary choice.

Thirdly, strategic plans of state-owned forest management are made in a top-down fashion and create many conflicts between the communities' needs and government's plans. It is critically important to find middle ground between local people's needs and government's plans.

Lastly, China's forest policy makers, forest managers, and field foresters are not familiar with critical concepts and methods of ecosystem management and biodiversity conservation. Convincing them to learn the new methodology may be the same tricky as that they are convinced by the new methodology (Shao *et al.* 2001). There is clearly a need to provide the forestry professionals with workable tools for practicing forest ecosystem management.

We intend to integrate these considerations into a computer-aided decision support system and develop a workable ecosystem management process through the use of the DSS.

A decision support system

A decision support system, FORESTAR (Forest Operation and Restoration for Enhancing Services in a Temperate Asian Region), has been developed in the environment of Map Object (http://www. esri.com/software/ mapobjects/index.html). It has three components corresponding to the first three prerequisites discussed above (Fig. 1). The *information component* is controlled with geographic information systems (GIS) containing spatial and attribute data on forest conditions and socioeconomic variables; the *ecosystem management component* consists of rule-based models and optimization schemes; the *middle ground* component is managed with an input interface that allows comparisons between the availability of resources and the required production from the resources. The output shows treatment locations and descriptions in tabular, graphic and map formats. FORESTAR is used for managing mountain forests in northeast China. The first version contains two sub-modules: Forest Operation and Forest Restoration (Fig. 2).

The Forest Operation sub-module contains four management choices (Fig 2a):

1. *Pursuing lucrative short-term wood production.* This management choice intends to represent the existing forest harvest system in forest industries (Shao and Zhao 1998). Its strategy is to minimize the costs of forest harvesting by cutting forests in compartments within connected slopes or watersheds near existing roads. The typical harvesting method is clearcutting.

2. *Regulating forest age structure.* Past forest management activities created an unsuitable forest age structure for sustainable forest management (Zhao and Shao 2002). Linear or nonlinear programming schemes are used to regulate forest age structure with maximizing long-term volume goals (Weintraub *et al.* 2000). Similar to management choice 1, this management choice does not have spatial concerns in choosing cutting targets.

3. *Maintaining landscape heterogeneity and integrity.* This management choice is a follow-up process of management choice 2. It intends to protect ecologically sensitive forests defined by NFCP, including forests that surround water bodies, habitats of 1st- and 2nd-priority endangered and rare species, and steep-slope ecological land types (Dai *et al.* 2003). It also prevents the cutting of adjacent compartments for at least ten years. Harvesting methods include small-area clearcutting and selective cutting. The combination of management choice 2 and 3 is

similar to the two-stage approach described by Boston and Bettinger (2001).

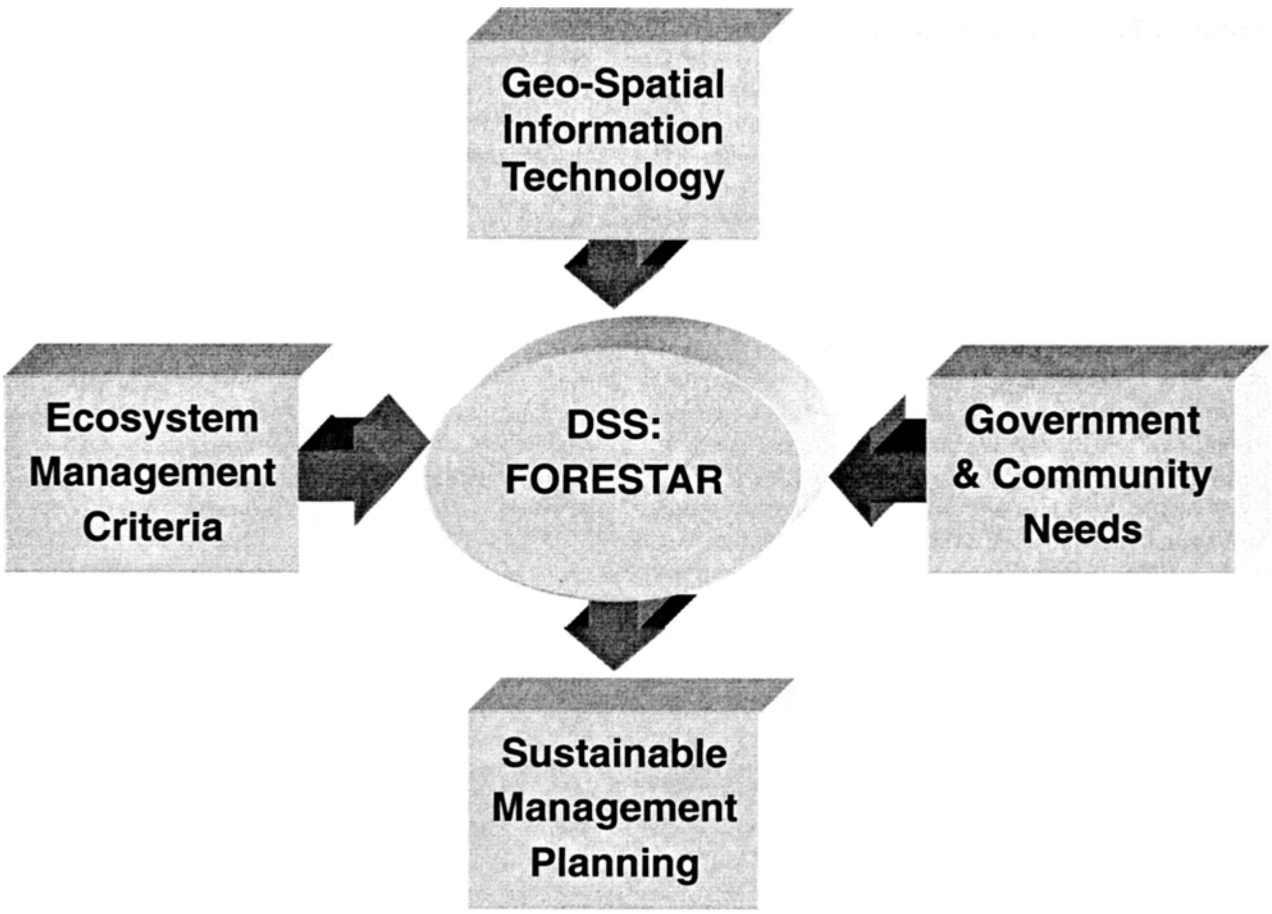

Fig. 1 The framework and controls of the decision support system FORESTAR.

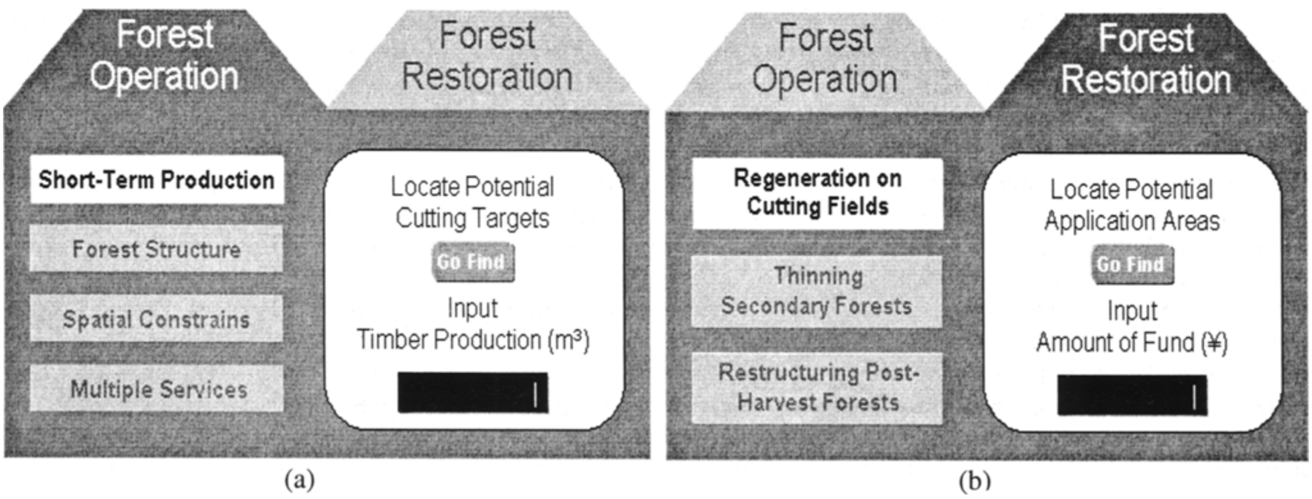

Fig. 2 The major interface of the decision support system FORESTAR version 1.

4. *Enhancing multiple services.* Management choices 1-3 are concerned with timber production as the major source of income. In northeastern China, non-timber products are becoming more economically important, including pine nuts (*Pinus korainsis*), frog meat and oil, mushrooms, ginseng, and ferns. Diversified management practices are applied to increase the production of these products in forested landscapes (Shao *et al.* 1996). For example, forests around frog ponds should be managed to maintain mixed-species and uneven-aged structures.

Corresponding to each management choice, the input interface contains two options (Fig. 2a). The first option allows users to search for all the harvestable forests; the second option allows users to locate cutting targets based on the required quantity of timber volume.

The Forest Restoration sub-module is developed in parallel with Forest Operation sub-module because the state-owned forest industries receive separate funds from the government for reforestation, afforestation, and forest tending. In northeast China, the forestry funds apply mainly to three categories of activities: forest regeneration on cutting fields (i.e. areas after clearcutting), thinning secondary forests, and restructuring post-harvest forests (i.e. forests after intensive removing of quality trees). Accordingly, the Forest Restoration sub-module contains three restoration choices (Fig. 2b):

1. *Forest regeneration on cutting fields.* Typical clearcutting in northeast China not only removes all the big trees, but also cleans all the understory vegetation. Artificial regeneration is an only effective reforestation approach. The number of seedlings/saplings of a tree species is determined by its proportion in a forest stand that is the most suitable for the site conditions.

2. *Thinning secondary forests.* Secondary forests are those naturally regenerated after clearcutting in the past 3-4 decades. The forests are dominated by pioneer species, including birch and aspen, in the canopy layer and by climax species, including pine, spruce, ash, basswood, and oak, in the succession layer. Thinning canopy trees is an effective way to promote the growth of desirable seedling/sapling species (Shao *et al.* 1996).

3. *Restructuring post-harvest forests.* The post-harvest forests in northeast China were developed after high-intensity and destructive logging of quality trees by the Japanese during World War II. These forests now have low tree densities and are dominated by low-value trees in the canopy and by shrubs in the understory. Altering both the species composition by planting seedlings and the size structure by thinning can speed the restoration of the mixed broadleaved-coniferous forest ecosystems.

The input interface of Forest Restoration sub-module also contains two options (Fig. 2b). The first option allows users to search for all the forestland requiring treatment and the total treatment costs; the second option provides users with information on which forestland that can be treated given a specified budget.

The roles of the decision support system

FORESTAR is developed for the real needs in sustainable management of China's existing and damaged natural forests but its acceptance in China's forestry system requires tests from real users. The design of the decision support system fulfills two goals: simple and effective. The *simple* means that the decision analysis process is transparent and clearly understandable to average forestry professionals. The goal of *simple* encourages users at different levels to "play" with the system. Chinese foresters have little experience in using decision-support computer programs. They can be scared away with complicated interfaces or operation processes before they can benefit from using DSS. The goal of *effective* intends to help Chinese foresters find alternative solutions in forest management planning. It convinces users that sophisticated decisions on forest management can be easily made with computer-aided planning but somewhat unachievable without the decision support system.

Users can examine possible forest management schemes by testing different choices. By comparing the differences and similarities in forest management among different choices, as demonstrated by Rauscher *et al.* (2000), users are able to point out the advantages and disadvantages of each management method. A compromise among different forest management methods can lead to an optimum decision on forest management. Such an exercise not only helps field foresters, forest managers, and policy makers make sound and consistent decisions in forest management planning, but also helps them change the way they think, communicate, and work. It is not the decision support system, but users, that will make the final decision on how to manage the forests. DSS attempt to bring together the intellectual flexibility and imagination of humans with the speed, accuracy, and tirelessness of the computer. The learning or education process within the decision support system may be more important than the decision making process itself. Thus a decision analysis process will gradually help satisfy the education prerequisite discussed in the second section. The "educated" users can share more information, knowledge, and skills, and therefore, are more able to work together and avoid making conflicted plans. As the decision support system becomes better understood, additional modules and choices, such as forest recreation and forest fire prevention, will be included. This kind of task is compatible with the open-architecture design of FORESTAR.

The current version of FORESTAR is used for forestry bureaus and sub-bureaus (forestry farms), equivalent to the range of forest-project levels defined by Rauscher (1999). The next version of the decision support system will be developed for regional levels of forestry units. By using DSS at different hierarchical levels, regional- or national-scale forestry planning will be consistent with lo-

cal-level forestry planning, realizing the efficient uses of financial and natural resources.

Concluding remarks

Today's ecosystem management remains primarily a philosophical concept for dealing with larger spatial scales and long-term frames. One concrete method to operationalize ecosystem management is to design and develop effective decision support tools (Rauscher 1999). This statement stands perfectly well to China's forestry system. China's new forestry programs provide political and financial possibilities of ecosystem management but their implementation processes need scientifically sound approaches. We found that there are fundamental differences in forest management practices between the computer-aided (proposed with the decision support system) and traditional forestry planning (Table 1), suggesting that the decision support system is useful to promote changes in forest management in China.

Table 1: A comparison of computer-aided and traditional forestry planning.

	Proposed Computer-Aided Planning	Traditional Planning
Spatial Pattern	Prevent connective cutting and fragmentation of ecologically sensitive forests	Cutting occurs in concentrated areas
Forest Structure	Diversified forest structure within a forestry unit	Even-aged monoculture management
Regeneration Methods	Mainly natural and partially artificial regeneration	Fully artificial regeneration
Forest services	Timber supplies, biodiversity conservation, and environmental protection	Timber supplies
Economic Income Resources	Timber and planned non-timber products	Mainly timber and non-planned non-timber products

The initial applications of FORESTAR will focus on the two forestry programs, progressing from local to regional scales. As a pioneer DSS in China's forestry, its role in managing China's forest ecosystems is beyond the functionalities within the software. It is useful to correct informational errors in forest resource assessment, solve conflicts between societal goals and local values, document ecosystem management concepts, turn the ecosystem management philosophical concept into a practical process, and realize a transition from traditional monoculture forestry to multi-objective forestry in China.

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